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Review

Review of Conventional Methods of Water Hyacinth Controls and Option for Niger Delta Region Nigeria

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Control of water hyacinth using conventional methods such as manual, mechanical harvesting, chemical and biological controls has been mostly employed globally. Though these methods have been greatly successful in controlling water hyacinth in some places, their cost was usually very high and unsustainable. This is particularly true of developing countries, where equipment, chemicals, machineries and even the expertise and technologies required to efficiently apply these methods are mostly imported. In Nigeria, particularly the Niger Delta region where water bodies are highly infested with water hyacinth, using these methods has obvious advantages and disadvantages. The study reviewed some conventional methods, the advantages and disadvantages of using the conventional methods of water hyacinth control in relation to the Niger Delta region. The methodology involved the review of relevant literature, passive application of selected methods in some areas in the region and field survey to physically asses the advantages associated with each method reviewed. The study concluded that though the disadvantages of employing the conventional methods of controlling water hyacinth far outweigh their advantages, but studies conducted in Southern Republic of Benin utilizing two weevil species (*Neochetina* spp.) showed that the biological control method has caused the reduction of water hyacinth cover in the water ways drastically with an increase in income of US$30.5 million per year from residents who experienced increase in trade primarily food crops and fish. Total cost of the control program was estimated at a value of US$2.09 million. The benefits accrued outweigh the costs by a ratio of 124:1 percent. Therefore from the advantages reviewed in this study on all conventional methods and the experimental result from Benin Republic this study recommends the biological control method as better option for the Niger Delta region as well as the unconventional methods that essentially convert water hyacinth into raw materials.

Key words: Review, Conventional- Methods, Water-Hyacinth, Control, Niger Delta.

INTRODUCTION

Hundreds of thousands of dollars are spent worldwide every year in an attempt to get rid of water hyacinth. Water hyacinth is considered the most damaging waterweed in the world because of

its very fast growth rate and its adaptation to a wide range of nutrient and environmental conditions (WHO, 1997). Thus, there has been national and international efforts aimed to tackle the menace of the plant in order to minimize and or eliminate the environmental and economic adverse effects of the plant. The control methods are broadly classified into four categories, namely:

1. Physical or Manual method
2. Mechanical Method
3. Chemical method
4. Biological method

Review of Choice of Control Methods

The choice of any control measure to be adopted in controlling water hyacinth is often determined by critical economic considerations and also the environmental implications of the methods to be used. For example, use of heavy machineries such as swamp boogies was not just cost ineffective for small scale infestations, but highly destructive to the ecology of the environment (Akinyemiju, 1987). Also the logistics of deploying such heavy machineries in the creeks of the Niger Delta for example can be extremely cumbersome and out rightly impossible in some cases. The manual physical control method involves a lot of drudgery and was highly hazardous with regards to the safety and health of the workers. Another critical factor was the convenience of both the physical and demographic characteristics of the environment in allowing the effective application of the perceived method of choice. Whereas the physical removal method was suitable for small infestations and less destructive to the ecology, it was slow and therefore unsuitable or ineffective for large infestations control. Chemical application methods, though very effective was quite hazardous to the environment due to toxicity effects from the residual effects of the chemicals and also the adverse effects on water quality due to putrefaction of the dead weed leading to eutrophication problems (Chikwenhere and Forno, 1991). A good example of such eutrophication problems was the issue of dissolved oxygen depletion after such treatments, leading to massive fish and other aquatic resources of economic importance mortalities. Biological control seem to be the most environmentally friendly. However, it was slow and can also lead to the problems associated with alien biological species wiping out other more beneficial native species. More so, the chemical and biological control methods require a relatively controlled environment, with highly minimized human interference for it to be successfully applied in the field, even on trial scales. This study examined the various control methods and a possible best practicable option for Niger Delta Region Nigeria. This approach was complemented with discussions from literatures on the reviewed methods of water hyacinth control, citing the advantages and disadvantages of each method (Grodowitz et al., 1991).

Physical or Manual Control Methods

Physical or manual control method refers to the process of removing the water hyacinth either manually using human labour either directly by pulling the water hyacinth by hand or by the use of small hand instruments like pitchforks, etc. It can also be removed by raking or seining it from the water surface. During the field work, the services of the local labour were employed to harvest the fresh water hyacinth from the rivers and creeks using local canoe. Cutlasses were used to cut the thick mats of the water hyacinth into smaller portions that can be easily lifted manually into the canoes for onward transportation to land where they are left to decay naturally. The physical control involves complete removal or uprooting of the water hyacinth plant including the glossy leafy portion, the vegetative rhizomes and the fibrous roots from the water body by pulling out of the plant from the water surface by hand.

Use of Machineries for Physical Control

Manual or physical removal was one of the best methods, this was usually done manually; for smaller infestations, in case of large infestations; it requires the use of a lot of aquatic machinery or aquatic weed harvesters. Also, it may require some terrestrial vehicles for transporting the weed removed from the water body. Since water hyacinth spread from South America to other continents in the 1880's, with devastating speed, it has tested human ingenuity in devising control techniques. Early control attempts concentrated on removing the plant from water with hand or instrument like pitchforks, then dumping the accumulated mass on land to die. This control method was costly in terms of time, money and energy and several of the

Plate 1. Manual Uprooting of Water Hyacinth.

Plate 2. Manual Uprooting and Loading into local canoe for Transportation.

procedures used damaged the ecology, affecting all animal life in the aquatic ecosystem infested by the water hyacinth (Grodowitz et al., 1991). The activities involved in the physical or manual control of water hyacinth have been shown in Plates 1 and 2 and 3.

Advantages

The advantages of manual clearance are as follows;

1. It is not harmful to the environment and,
2. It also creates job opportunities being labour intensive.
3. It requires very little skill and therefore very minimal or no training.
4. It can therefore be said to be generally cheap

Disadvantages

1. This method was only effective in small areas and as long as the water was not deep.
2. This method was that when the water is polluted, the workers need to wear protective gears, thus increasing the cost of control.
3. Manual removal of water hyacinth was suitable only for extremely small areas as it was difficult, labour intensive and in some areas there are serious health risks

Plate 3. Water Hyacinth Loaded and Ready for Transportation to the Shore.

associated with the work (Attacks by crocodiles, hippopotamus and other dangerous aquatic organisms can occur).

4. The cost of this transportation can be enormous, as the weed was too heavy due to the high water content.

Installation of floating barriers

One of the Physical control methods adopted for the management and control of water hyacinth was the installation of floating barriers at strategic locations to forestall the movement of water hyacinth to other areas. This floating barrier was based on the concept of aggregation of water hyacinth for easy evacuation. The floating barriers where it was used as an option had drastically reduced the influx of water hyacinth especially from Niger Republic.

Advantages of floating barriers

1. A large volume of the weed which ordinarily would have drifted down the river is trapped by the facility at the point of installation thus making the evacuation of weeds relatively easy for those engaged in the service.
2. Fishing activities downstream the barrier site gets improved tremendously in terms of fishing activities as a result of the riddance of the obstruction from the water hyacinth in fishing grounds. This is used to contain and limit the spread of the plant within an area.
3. It is cheap to install and maintain as different kinds of materials can be used to construct the barriers.

Disadvantages of floating barriers

1. Procurement, installation and maintenance of the barriers can be costly.
2. It can lead to ecological disruptions both up and downstream of the barrier
3. It can therefore lead to socio-economic conflicts between the various communities up and down stream of the barrier.
4. This can only be used in a small area.
5. It does not eradicate or kill the plant and thus it is not an effective method.

Mechanical Method

Mechanical removal of water hyacinth was seen as the best short-term solution to the proliferation of the plant. It was done using land-based 'clamshell' bucket cranes, draglines or booms or, alternatively, water based machinery such as mowers, dredges, and barges or specially designed aquatic weed harvesters.

Advantages of Mechanical control

1. Mechanical control was generally effective over an intensive and wide area for immediate short term results.

Disadvantages of Mechanical control

1. Many of these techniques require the support of a fleet of water and land-based vehicles for transporting the large quantities

of water hyacinth.
2. Mats of water hyacinth can be enormous and can have a density of up to 200 tonnes per acre.
3. Transportation of the harvested weed was therefore very costly, because it has such high water content.
4. It was generally damaging to the environment and aquatic resources through major disruptions of the natural ecological balance.

Some of the various mechanical methods are highlighted as follows:

Excavators

They are used to pull out the water hyacinth out of the river or dam.

It was a very successful way of clearing the weed. This method was environment friendly as it does not pollute the environment. It however has the following disadvantages as follows;

1. The machines are expensive to buy, repair and maintain.
2. The machines need fuel to operate making them expensive to use.
3. Skilled manpower was required to operate the machines, thus increasing the cost of their usage.
4. The machines may damage the river banks, fishing nets and other properties near the water ways.
5. Pieces of the plant that are cut and not cleared away will grow again, leading to re-infestation of the environment.
6. In case of large infestations, it requires a whole lot of aquatic machinery or aquatic weed harvesters and also requires some terrestrial vehicles for transporting the weed removed from the water body.

Boats and Shredders

According to (Charudattan et al., 1996), these are used in areas where machines cannot access in the water ways. They can move into deeper water. The water hyacinth mat may be broken up by the shredder; the boom would be used to bring the shredded mats to the shore, where they are dumped.

Disadvantages

1. The methods though do not pollute the environment, but can aid in the spread of the plant if the shredded parts are not at all taken ashore. It was also expensive because of the cost of acquisition, repair and maintenance, fuel and skilled personnel needed to operate the machines.

Suction Dredging

This involves harvesting the plant using a suction dredger, moving the harvested plant to the shore, drying and burning of the plant.

Disadvantages

2. This method pollutes the environment when the plants are burnt.
3. It is very expensive to purchase the dredger, repair and maintain.
4. The cost of fuelling and skilled labour required to operate the dredger makes the method uneconomical.
5. It disrupts the ecological balance and destroys aquatic organisms

The mechanical control methods of water hyacinth have not been effective in reducing the plant population because of the following reasons:

1. They are only successful for small, isolated areas like ponds and lakes.
2. There was risk of re-sprouts from cut mat fragments that are not removed.
3. There was the problem of submerged trees that can damage excavators, boats and dredgers.
4. It was an expensive method; Harvesting costs are estimated to range from $500 - $800 per acre with additional cost for mobilization and equipment raising the cost to about $35,000-$100,000 per acre. The harvesting costs vary depending on the plant density, location, equipment type, transport fees for the removal of harvested materials, cost of labour for skilled operations, among others. They estimated that where manual labour was used to harvest the plant, it cost $500 - $2400 per day to pay labour to harvest a small area apart from additional cost for transport and disposal of plant

Plate 4. Force Up Chemical Displayed in the Canoe.

Plate 5. Force Up Chemical Opened and Mixed for Spraying.

materials. The seeds of the plant remain viable for many years, and even when the plants are removed, the seeds germinate, creating a new infestation, (USEPA, 1998).

Chemical Control Method

The third method reviewed was the chemical control method. As the name rightly suggests, chemical control implies the use of chemicals, in the form of herbicides, like, 2,4-D, Diquat, Glyphosate, etc. The application can be from the ground or from the air and requires skilled operators. Relevant literature on the use of chemicals (Herbicides) was reviewed to help study this delicate method of water hyacinth control.

Experimentation on use of Chemical Control Method

The herbicides (**FORCE UP AND BUSHARE BRANDS)** were diluted according the instructions on the material safety data sheet and it was sprayed using a knapsack sprayer with fine nozzles as shown in Plates 4 5, 6, 7 , 8, 9, and 10 respectively. It required the use of canoes to paddle along as the chemical was being sprayed.

Though, the chemicals used were reported to be very effective as virtually all the sprayed weeds were reported to have died after a few days of treatment. However, it posed the problem of eutrophication and dissolved oxygen depletion, thereby resulting in serious ecological problems (Caunter and Seeni, 1991).

Plate 6. Bushare Chemical Displayed.

Plate 7. Bushare Chemical Mixed for Spraying on the Water Hyacinth.

Advantages of chemical control method

1. It was easier to deploy in covering very intensive and large areas of infestation.
2. It is relatively more economical than the physical method;

"The reported best chemical control was achieved with 2, 4-D dimethyl amine 58% (4 kg ha^{-1}) and that the cost of removal by this herbicide was 61% less than that of manual weeding (Mailu 2001)".

Disadvantages

1. Though, this method was found to be successful in the control of water hyacinth infestations, there are environmental concerns regarding their persistency in the water bodies. The chemicals can get into the food chain through bioaccumulation and bio magnification.
2. Another drawback was the need for skilled persons for application of these herbicides and they may affect the life of other aquatic animals and plants as well as humans, who use the water.
3. Pesticide scares and groundwater contamination have made the general public quite wary when plans are proposed to put chemical into water (Ndimele and Jimoh, 2011).
4. The impact of chemical control on the environment was always raised as the

Plate 8. Bushare Chemical Sprayed on the Water Hyacinth.

Plate 9. Bushare Chemical Sprayed on Highly infested Section of the Waterways.

eradication of plants including water hyacinth in water body as it may negatively affect the populations of fish.

5. Sometimes, the water where the herbicides are sprayed could not be used for irrigation or human consumption for long period of time and the fauna in the ecosystem were negatively affected.
6. It can lead to serious water quality problems such as dissolved oxygen problems, resulting in mass mortality of aquatic organisms such as fish.

Brief Review of Literature on Chemical Control of Water Hyacinth

Fish abundance (7 species) and Catch (Catch per unit effort) at pre-treatment period was 13 kg increased significantly ($p<0.5$) to 13 species and 75.13 kg, respectively in the post-treatment period. Public health assessment showed that glyphosate had no adverse effect on the population during the herbicidal treatment and afterwards. The use of chemical control method has always faced stiff opposition as environmentalists always kick against

Plate 10. Bushare Chemical also Sprayed on another infested Section of the Water ways

Plate 11. Weevil Pest utilized as a Biological Control Pest

its use because of the potential effects on the environment. The use of chemicals for aquatic vegetation control was one issue commonly surrounded with fear and uncertainty by general public, environmental groups and politicians. Some environmentalists argue that chemical control of aquatic plants treats the symptom rather than the source of the problem. The impact of chemical control on the environment was always raised as the eradication of plants including water hyacinth in water body as it may negatively affect the populations of fish. Pesticide scares and groundwater contamination have made the general public quite wary when plans are proposed to put chemical into water (Ndimele and Jimoh, 2011). The chemical method involves the use of herbicides (weed killers) to control water hyacinth. Various kinds of herbicides have been used in different

Plate 12. Weevil pest utilized as a Biological Control Pest.

places to control the plant and there are many ecological problems caused by the use of these herbicides. Sometimes, the water body where the herbicides were sprayed could not be used for irrigation or for domestic use for long period of time and the fauna in the ecosystem were negatively affected (Julien, 1998). They also reported that the best chemical control was achieved with 2, 4-D dimethyl amine 58% (4 kg ha) and that the cost of removal by this herbicide was 61% less than that of manual weeding (Mailu, 2001). The application can be from the ground or from the air and requires skilled operators. The main concern when using herbicides was the environmental and health related effects, especially where people collect water for drinking and washing. This method was effective in the control of water hyacinth, but has several adverse environmental and economic effects, which could discourage its use due to some of the dangers mentioned especially as it relates to human health and environment.

Classification of Herbicides

Herbicides can be classified according to their activity, use, chemical composition, mode of action, or the type of vegetation controlled.

Classification of Herbicides by Activity

1. **Contact** herbicides destroy only the plant tissue in contact with the chemical. Generally, these are the fastest acting herbicides but they are less effective on perennial plants, which are able to regrow from rhizomes, roots or tubers.
2. **Systemic** herbicides are trans-located through the plant, either from foliar application down to the roots, or from soil

application up to the leaves. They are capable of controlling perennial plants and may be slower-acting, but ultimately more effective than contact herbicides.

Recently, the term "organic" has come to imply products used in organic farming. Under this definition, an organic herbicide was one that can be used in a farming enterprise without adverse environmental effects. Commercially sold organic herbicides are expensive and may not be affordable for small scale farming (WHO, 1997). Depending on the application, they may be less effective than synthetic herbicides and are generally used along with cultural and mechanical weed control practices. The commonly used organic herbicides include:

1. **Corn gluten meal** (CGM) is a natural pre-emergence weed control used in turf grass, which reduces germination of many broadleaf and grass weeds.
2. **Vinegar** is effective for 5-20% solutions of acetic acid, with higher concentrations most effective, but it mainly destroys surface growth, so re-spraying to treat regrowth was needed. Resistant plants generally succumb when weakened by re-spraying.
3. **Steam** has been applied commercially, but was now considered uneconomical and inadequate. It kills surface growth but not underground growth and so re-spraying to treat regrowth of perennials was needed.
4. **Flame** was considered more effective than steam, but suffers from the same difficulties.
5. **D-limonene** was a natural degreasing agent that strips the waxy skin or cuticle from weeds, causing dehydration and ultimately death.
6. **Monocerin** produced by certain fungi will kill certain weeds such as Johnson grass.

Application of Herbicides

Proper application of herbicides was just as important as selecting the correct chemical to control the weed problem. Herbicides are best applied when plants are young and growing rapidly. Herbicide penetration and translocation are usually at a maximum before the plant reaches maturity. The method for applying on an aquatic herbicide depends on the material being used and the weed to be controlled. It was recommended to apply liquid herbicides by injecting or metering into the water behind a boat; apply granular products by hand or a hand-cranked spreader from the bank or from a boat, soluble crystals (copper sulfate) can be put in burlap bags and either suspended or dragged through the water until they dissolve, other herbicide treatments require spraying the herbicide directly over the plant or on the water surface. Herbicides can be applied with pump type, backpack sprayers or motorized sprayers operated from boats (FAO/UN 1998).

Surfactant and Carriers

The leaves of many floating and emerged aquatic plants have thick, waxy coatings that cause water-soluble herbicides to bead on the surface and reduce the exposure of the plant to the herbicide. Adding a small amount of a detergent-like substance, called a surfactant, to the herbicide-water solution promotes spreading of the solution and provides better coverage of the plant surfaces. Most herbicides are applied as water-based sprays using ground equipment. Ground equipment varies in design, but large areas can be sprayed using self-propelled sprayers equipped with long booms, of 60 to 80 feet (18 to 24 m) with flat-fan nozzles spaced about every 20 inches (510 mm). Towed, handheld, and even horse-drawn sprayers are also used for the application of herbicides. According to (USEPA, 1998) Synthetic organic herbicides can generally be applied aerially using helicopters or airplanes, and can be applied through irrigation systems. A new method of herbicide application involves ridding the soil of its active weed seed bank rather than just killing the weed. Researchers at the Agricultural Research Service (FAO/UN, 1998) have found the application of herbicides to fields late in the weeds' growing season greatly reduces their seed production, and therefore fewer weeds will return the following season. Because most weeds are annual grasses, their seeds will only survive in soil for a year or two, so this method will be able to “weed out” the weed with only a few years of herbicide application.

Chemical usage in parts per million (ppm)

Some aquatic herbicides list the quantity to be applied in the final concentration of the pond water in parts per million. This quantity may refer to the commercial product or the active ingredient within

the product. According to (Westerdahl, and Getsinger, 2000), to find ppm on a weight basis, the following formula can be used:
W = A x D x C x 2.72, where
W = number of pounds of herbicide product required.
A = area of the water surface in acres.
D = average depth in feet.
C = final concentration desired in ppm.
When oil-soluble herbicides (such as 2,4-D esters or oil-soluble amines) are mixed with water, it was advisable to use an emulsifying agent and constantly agitate the mixture to prevent separation of the oil and water and this mixture (emulsion) should have a milky appearance.

Chemical Application Rate of Herbicides

The species chemical ingredient rates of application of some herbicides are given below:

PARAQUAT GLYPHOSATE

The application rate varies from 0.5kg/ha – 2 kg/ha depending on the level of infestation and the environment it was applied.

NYMPHAEA SP 2,4-D (20%G)

The application rate is 2.26kg/A

2,4-D ESTER 2,4-D AMINE PARAQUAT

The application rate varies from 0.5kg/ha - 1kg/ha depending on the level of infestation and the environment it is applied (FAO/UN, 1998).

CERATOPHYLLUM DEMERSUM 2, 4-D ESTER

The application rate is 2ppm/ha. Different herbicides have been used for the control of the water hyacinth. This method was effective in the control of water hyacinth, but has many adverse environmental and economic effects, which discourage its use. They reported that different chemical substances have been used in search of solution to the plants menace. Farmers have been employed to do the spraying along the rivers in ponds and lakes, helicopters, small planes and micro-lights are also used to spray large areas like dams.

Effects of Chemical Control on Aquatic Biodiversity

Governments and organizations have tried to control water hyacinth using chemicals, but they are not effective because the plant almost always come back/(re-sprouts) once the herbicides have worn off. Also the herbicides kill non-target economic plants, organisms, and fishes etc and persistent. One danger with any chemical control method was the chance of oxygen depletion after the treatment caused by the decomposition of the dead plant material. Oxygen depletions can kill fishes and other aquatic organisms in the pond. If the pond was heavily infested with weeds it may be possible (depending on the herbicide chosen) to treat the pond in sections and let each section decompose for about two weeks before treating another section. Aeration particularly at night, for several days after treatment may help control the oxygen depletion. One common problem in using aquatic herbicides was determining area and or volume of the pond or area to be treated. Many aquatically registered herbicides have water use restrictions and the labels or Safe Handling of Chemical (SHOC) cards should be read to for specific water use restrictions. One danger with any chemical control method is the chance of oxygen depletion after the treatment caused by the decomposition of the dead plant material. Oxygen depletions can kill fish in the pond. If the pond is heavily infested with weeds it may be possible (depending on the herbicide chosen) to treat the pond in sections and let each section decompose for about two weeks before treating another section. Aeration particularly at night for several days after treatment may help control the oxygen depletion (Mitchell et al., 1990).

Biological Control Methods

Biological control within this contest and in its simplest form can be described as the use of the natural pests of the plant to control the growth of the plant. These pests can be native or exotic species introduced into the environment just for the sole purpose of controlling the water hyacinth. The kinds of organisms that can be deployed as biological control agent range from the very minutes, such as microbes like fungi, through weevils, to macro vertebrates/invertebrates such as herbivorous species like the Chinese carp. However, certain precautions must be exercised prior to the

introduction of particularly exotic species as a means of controlling water hyacinth. This was because certain exotic species may become so successful that they wipe out the native species that also constitutes a very important part of the ecological balance of that the particular niche (Julien and Griffiths, 1998). Despite this note of caution, Biological control was generally considered the most cost effective and environment friendly control method for water hyacinth and other aquatic weeds. Essentially, this aspect of the research focused on review of available literature on water hyacinth control using the natural pests of the weed such as fungi and weevils and fishes. Their advantages and disadvantages of biological control methods were also highlighted. Case studies globally and locally cited, as a means of providing the much needed information for the data base of water hyacinth control in the region, for future researches.

Global and local case studies of biological control

In recent years, focus has shifted to natural enemies of water hyacinth including plant pathogens (Dagno et al., 2012). The aim of any biological control was not to eradicate the weed, but to reduce its abundance to a level where it was no longer problematic. While there exists several native enemies of water hyacinth, two South American weevil beetles (*Neochetina eichhorniae* and *Neochetina bruchi*) and two water hyacinth moth species (Niphograpta albiguttalis and Xubida infusella) have had effective long-term control of water hyacinth in many countries, notably at Lake Chivero (Zimbabwe), Lake Victoria (Kenya), Louisiana (USA), Mexico, Papua New Guinea and Benin (Dagno et al., 2012). Researchers have identified another tiny insect, *Megamelus scutellaris,* from South America which was highly host-specific to water hyacinth and does not pose a threat to native or economically important species. The weevils reduce water hyacinth vigour by decreasing plant size, vegetative reproduction, and flower and seed production. They also facilitate the transfer and ingress of deleterious microorganisms associated with the weevils (both fungi and bacteria) into the plant tissues (Van et al., 2010). Control of water hyacinth using fungal pathogens has greatly stimulated interest in the management of the weed. Several fungal species among theme *Cercospora rodmanii, Alternaria alternata* and *A. eichhorniae* are recognized as potential mycoherbicide agents although no commercial mycoherbicide is available for water hyacinth (Dagno et al., 2012). Biological control was considered as the only effective, permanent and environmentally friendly methods. The adoption of this method recorded a notable success in Argentina, India, Sudan and USA (Julien and Griffiths, 1998) using *N. eichhorniae* and *N. bruchi*. Based on this information, a consignment of 2527 Neochetina weevils were imported into Nigeria in 1992. The first release was in 1993, Since then at least nine more releases had been made to River Niger while releases were done to lekki lagoon Nigeria (Neuenschwander et al.,2005). The effectiveness of *Neochetina* sp. as effective biological control agent for water hyacinth was affirmed judging from the presence of numerous holes caused by them on water hyacinth plants (Dagno et al., 2012). Nigerian government has strengthened National Institute for Horticultural Research and National Institute for Freshwater Fisheries in order to enable them breed large quantities of these weevils. This invariably means that these Institutes will be the source of supply to other areas and ultimately lead to its exportation to other countries like Niger and Benin Republics in the West African sub-region (Oko et al., 1988).

Characterization of Major Arthropods Used to Control Water Hyacinth

Table 1 shows the characteristics of major arthropods used to control water hyacinth. The information in the table provides a very good guide in selecting control pests for the control of water hyacinth either in Niger Delta or elsewhere. Depending on the type or peculiarities of the weed to be controlled, the environment and objective, the characterization provided in Table 1 becomes a handy guide for the choice of pests to be deployed.

Advantages of Biological Control Method

Between 1991 and 1993, a biological control program of water hyacinth was undertaken in Southern Benin. It consisted of the release of three natural enemies, two weevil species (these are the two *Neochetina* spp.) and one moth that feed exclusively on water hyacinth. In 1999, a survey of 365 men and women from 192 households in 24 villages in the target area revealed that water hyacinth, although not eliminated, was perceived by

Table 1. Characterization of Major Arthropods Used to Control Water Hyacinth.

Species	Field and Laboratory Host Plants	Attributes, Limitations, and Current Status of Research
First Priority - Agents in Use Worldwide		
1.*Neochetina eichhorniae* Warner (Col.: Curculionidae)	*E. crassipes*	In use in North America, Australia, Africa and Asia (Julien and Griffiths, 1998)
2. *Neochetina brunchi* Hustache (Col.: Curculionidae)	*E. crassipes*	In use in North America, Australia, Africa and Asia (Julien and Griffiths, 1998)
3. *Niphograpta albiguttalis* (Warren) (Lep.: Pyralidae)	*E. crassipes*	In use in North America, Australia, Africa and Asia (Julien and Griffiths, 1998)
4.*Orthogalumna terebrantis* Wallwork (Acarina: Galumnidae)	*E. crassipes, E. azurea, Pontederia cordata, Reussia subovata*	In use in North America, Australia, Africa and Asia (Julien and Griffiths, 1998)
Second Priority - Candidates Recently Released or Under Testing		
5.*Eccritotarsus catarinensis* (Carvalho) (Heter.: Miridae)	Field: *E. crassipes*, Lab.: *E. crassipes*, *P. cordata*, Heteranthera, Monochoria	Heavy attack at Belem, Brazil,Tested in South Africa, liberated in 1999 and established.Cilliers,et al.,2000)
6. *Xubida* (Acigona) *infusellus* (Walker) (Lep.: Pyralidae)	Field: *E. crassipes, E.azurea, P.cordata, P. rotundifolia*	Liberated in Australia September 1981; not established. Reimported in 1995 and liberated in 1996 (Julien and Griffiths 1998)
7. *Cornops aquaticum* (Bruner) (Orth.: Acrididae, Leptysminae)	Field: *E. crassipes, E. azurea, P. cordata*	Testsing underway in quarantine in South Africa (Julien and Griffiths 1998)
8. *Bellura densa* (Walker) (Lep.: Noctuidae)	Field:*P.cordata, E.crassipes, Colocasia esculenta*	Testing underway on quarantine in South Africa. Release rejected as hazard to *Colocasia esculenta* (Julien and Griffiths 1998)
9. *Paracles (=Palustra) tenuis* (Berg) (Lep.: Arctiidae)	Field: *E. azurea, P. cordata, E. crassipes* Lab.: Various plants in different families	Polyphagous in laboratory testing. It developed readily on *P.rotundifolia,Alternanthera,Canna, Limnobium*, and *Sagittaria*. Rejected from consideration (*Cilliers et al*, 2000)
10. *Thrypticus* spp. - Seven species- (Dip.: Dolichopodidae)	Field: *E. crassipes, E. azurea, P. cordata,* and *Pontederia subovata*	Under study at SABCL. Two species apparently monophagous on water hyacinth. Very Promising (*Cilliers et al.*, 2000)

Table 1. Continue.

Third Priority - Candidates Poorly Known or of Questionable Specificity		
11. *Brachinus* sp. (Col.: Carabidae)	Field: *E. crassipes, E. azurea,* *P. cordata* and perhaps others	Feeding on flowers (Silveira Guido, 1965). May be the same as the *Callida* sp. found in Argentina (*Cilliers et al.,* 2000)
12. *Argyractis subornata* Hampson (Lep.: Pyralidae)	Field: *E. crassipes* and perhaps others. Lab: *E. crassipes* and *Pistia stratiotes* L.	Root feeder; life history and biology studied by (*Hill et al*., 1999)
13. *Macocephala acuminata* Dallas (Heter.: Pentatomidae)	Field: *E. crassipes* and perhaps others	Root feeder; a pest of rice (*Hill et al*., 1999)
14. *Taosa inexacta* Walker (Homoptera: Dictyopharidae)	Field: *E. crassipes, P. rotundifolia* and perhaps others.	Feeding weakens plants and hastens deterioration; moderate degree of specificity (*Hill et al*., 1999)
15. *Megamelus electrae* Muir and *Megamelus scutellaris* Berg (Hom.: Delphacidae)	Field: *E. crassipes, E. azurea, P. cordata*, and perhaps others	Trinidad to Argentina. No visible damage caused to plants High levels of damage seen in Rio Janeiro, Brazil, in (*Hill et al*., 1999)
16. *Eugaurax setigena* Sabrosky (Diptera: Chloropidae)	Field: *E. crassipes, E. paniculata* and perhaps others	Little known on food habits; *Eugaurax floridensis* Malloch reared from *Sagittaria falcata* Pursh. *Eugaurax quadrilineata* reared from eggplant (*Hill et al*., 1999)
17. *Chironomus falvipilus* Rempel (Diptera: Chironomidae)	Field: *E. crassipes* and perhaps others	In petioles of waterhyacinth in Surinam and Brazil. Undetermined chironomid from Uruguay (Julien and Griffiths 1998)
18. *Hydrellia* sp. (Dip.: Ephydridae)	Field: *E. crassipes, P. lanceolata* and perhaps others	Common in Uruguay (Julien and Griffiths 1998)
19. *Flechtmannia eichhorniae* (Acarina: Eriophyidae)	Field: *E. crassipes* and perhaps others	Described for Brazil Mentioned from Uruguay as being a new species and genus; host specificity is promising (Julien and Griffiths 1998)

the villagers as having been reduced from a serious pest to one of minor or moderate importance (Calvert, 2002). At the peak of the infestation water hyacinth had reduced the yearly income of this population of about 200,000 by approximately US$84 million. Lost revenues for men were mostly in fishing, while women experienced lost revenues in trade, primarily food crops and fish. The reduction of water hyacinth cover through biological control was credited with an increase in income of US$30.5 million per year. The total cost of the control program was estimated at a present value of US$2.09 million. The benefits therefore appear to outweigh the costs by a ratio of 124:1 (Neuenschwander et al., 2005).

CONCLUSION

The use of manual or mechanical control of our

water hyacinth in the Niger Delta will be too expensive to sustain and also highly destructive to the ecosystem. Thus, it is recommended for use only in special cases where speed is required and the terrain makes it necessary to be used over a certain area. The Niger Delta terrain requires very expensive machines before it can be accessed. It is therefore economically unrealistic to use machineries for water hyacinth control. Some of the methods such as floating barriers and manual removal can be carefully adopted depending on its suitability for the area intended. The highest economic efficiency could be achieved with chemicals that are able to eradicate the water hyacinth weed within the stipulated time period at the least possible cost including safety of its application and use. The economic efficiency of chemical in controlling water hyacinth was a function of its percentage active ingredient, rate of application and its lapse time in the water environment. Herbicides use today has much more environmentally acceptable properties. They are characteristically biodegradable or become biologically inactive. These products include endothall compounds, Diquat and 2,4-D esters and amines among others. Chemical control of aquatic weeds has become of increasing importance due to greater awareness of the need for efficient and effective weed control. The application of herbicides for controlling water hyacinth has been carried out for many years and it has been found that there is a good success rate but a main concern when using herbicides is the environmental and health related effects, especially where people collect water for drinking and washing as some of them are persistent in the water body (Mailu, 2001). From the foregoing therefore, the best option for the Niger Delta Region would be the Biological control method, going by its positive result in Southern Benin in West Africa sub region where increase in income of fishermen and farmers was increased up to the tune of US$30.5 million per year after the eradication of the water hyacinth through Biological control at an estimated control programme cost of about US$2.09 million.

REFERENCES

Akinyemiju OAM (1987). Invasion of Nigerian waters by water hyacinth. Journal of Aquatic Plant Management; 25: 24-26.

Calvert WG (2002). Emergency Control of Water Hyacinth in Lake Victoria, Uganda. FAO/UN Mission Report, Tech. Co-op. Prog.,TCP/RAF/2371.

Caunter IG and Seeni M (1991). The effect of *Neochetina eichhorniae* and *Myrothecium roridum* alone and in combination for the initial biological control of water hyacinth. J. Plant. Prot. Tropics; 7: 133-140.

Charudattan R, Ricardo L, Ted-D- C and Christine Kelly –Begazo (1996). UNO/FOA, University of Florida.GennesVille. USDA/ARS Aquatic Plant Control Research laboratory, Florida, U.S.A.

Chikwenhere GP and Forno IW (1991). Introduction of *Neohydronomus affinis* for Biological control of *Pistia stratiotes* in Zimbabwe. J. Aquat. Plant Manage; 29: 53-55.

Cilliers CJ, Campbell PL, Naude D and Neser S (2000). An Integrated Water Hyacinth Control Program on the Vaal River,in a Cool, High Altitude Area in South Africa.

Food and Agricultural Organization (FAO/UN, 1998) Water Hyacinth Surveillance and Control in Uganda. Terminal Statement, TCP,FI: TCP/UGA/9153.

Grodowitz MJ, Stewart RM and Cofrancesco AF (1991). Population dynamics of water hyacinth and the biological control agent *Neochetina eichhorniae* (Coleoptera: Curculionidae) at a southeast Texas location. Envir. Entomol., 20: 652-660.

Hill RW and Bennett FD (1999). Biological control of water hyacinth on the White Nile, Sudan. Pp. 491-496 in: Proc. VI. Intern. Symp. Biol. Contr. Weeds, Univ. British Columbia, Vancouver, B. C. Canada, 19-25, E.S. Delfosse, Ed., Agriculture Canada, Ottawa.

Julien MH (1998). Biological Control of Weeds: A World Catalogue of Agents and Their Target Weeds. Third ed. CAB International, Wallingford.

Julien MH and Griffiths MW (1998). Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds. 4th edition. ABI Publishing, Oxford, pp. 90-96.

Mailu FD (2001). Biological control of aquatic weeds . UNEP Res. AndProurement Series 7 Nairobi, Kenya, pp. 320-323.

Mitchell DS, Pieterse AH and Murphy KJ (1990). Aquatic weed problems and Management in Africa. Pages 341-354 in: Aquatic Weeds. The Ecology and Management of Nuisance. Aquatic vegetation, A. H. Pieterse and K. J. Murphy, Eds.,

Oxford Science Publ., Oxford.
Ndimele PE and Jimoh AL (2011) A review on the phytoremediation of petroleum hydrocarbon. Pak. Journal of Biological Science; 13:715-722.
Neuenschwander P, Ajuonu O and Schade V (2005). Biological Control of water Haycinth in Benin, West Africa.Plant Health Management Division International Institute of Tropical Agriculture Cotonou, Benin.
Oke OL, Imevbore AMA and Farri TA (1988). Invasion of Nigerian Waterways by Water Hyacinth: Ecological and Biological Observations. Proc. of the Int. Workshop on Water Hyacinth, Lagos, Nigeria.
United States Environmental Protection Agency (USEPA, 1998) Design Manual Constructed Wetlands and Aquatic Systems for Municipal Wastewater Treatment. U.S. Environmental Protection Agency. Report no. EPA/625/1- 88/022. Office of Research and Development, Cincinnati, OH, 83.
Van Thielen, Ajuonu R, Schade VO, Neuenschwander VP, Adit ÄA and Lomer CJ (2010). Importation, releases, and establishment of *Neochetina* spp. (Col,:Curculionidae) for the biological control of water hyacinth, *Eichhornia crassipes* (Lil.: Pontederiaceae), in Benin,West Africa. Entomophaga, 39: 179-188.
Westerdahl HE and Getsinger DK (2000). Aquatic plant identification and herbicide use guide. Vol. 1 Aquatic herbicides and application equipment. Aquatic Plant Control Res. Prog. Tech. Rep A-88-9. U. S. Army Corps of Engineers. Vicksburg, Mississippi, USA.
World Health Organization (1997) Report on Problems and Environmental Impacts of Water Hyacinth. Page 5 in: Proc. 2nd Workshop on Water Hyacinth, Kampala, Uganda.